TEACHING DESIGN THEORY TO ENTREPRENEURS: AN EFFECTUAL USE OF DESIGN

M. Agogué, M. Lundqvist, K. Williams Middleton

Keywords: teaching design theory, entrepreneurship, effectuation

Abstract

To date, there is very little documented evidence around entrepreneurs applying design theory into their creation of new product and ventures. This is remarkable given the wide-spread view that many entrepreneurs are innovative designers of new products, services and ventures. One explanation to this lack of understanding is that both entrepreneurship and design thinking has been biased towards a more predictive and causal logic, missing out on more generative and effectual aspects of entrepreneurial behaviour. This study is a first attempt to study how entrepreneurship students behave and reflect when introduced to a design theory – C-K theory – that stands out in enabling both the generation of new concept and knowledge as well as ways to also converge upon preferred concepts. C-K theory is thus not biased towards either causation or effectuation and thus offers a tool for studying entrepreneurial behaviours as well as entrepreneurial perceptions. The results show that, in the application of C-K theory principles, the entrepreneurs illustrate use of effectual logic, allowing for expansive and robust mapping of different pathways. However, in their own interpretation of the use of C-K theory, they interpret their applied logic in a more causal frame, associating the path development to an initially set goal. This indicates that effectual capabilities are developed in action, whereas such behaviours end up being interpreted in more causal terms when reflected upon in hindsight. Conclusions are drawn around how C-K design theory can be used and further explored in entrepreneurship education. Furthermore, design theory is also argued to offer improved study of entrepreneurial behaviour and identity.

1. Introduction: the limits of project and knowledge management tools for managing advanced engineering design

Understanding the design process of entrepreneurs is critical, as entrepreneurs are seen to be the proposers of truly novel ideas and designers of radically new products. Literature on product development tends to see the design process of entrepreneurs as a relatively linear one: once an initial opportunity is clearly identified, resources are aligned to facilitate a design process allowing the entrepreneur to propose a new product, a new service and/or a new business model. This linear process can be seen as following a causal logic. However, more recent literature has presented an alternative logic, effectuation, emphasizing the development of products or services initiating from the means of the entrepreneur, and through iterative cycles, eventually converging on a created opportunity (Sarasvathy, 2008, Sarasvathy and Dew, 2005). Effectuation is described as decision-making logic used by entrepreneurs in situations of uncertainty, in collaboration with committed stakeholders. The use of effectual logic is argued as enabling entrepreneurs to co-create new and unanticipated effects from known means (Sarasvathy, 2008), hence underlining a generative design process.

Effectuation is in an adolescent stage of theoretical development, lacking in significant validation from empirical study (Chandler et al., 2011, Perry et al., 2011). As such, there is still much to be explored and explained regarding tools and methods that can help entrepreneurs support use of effectual logic. If effectuation describes the controlled capacity of entrepreneurs to explore new opportunities jointly with committed stakeholders, the means they have in such a design process remains to be discussed.

Moreover, supporting an effectual logic requires the use of methods that model the generativeness of a design process, i.e. the possible different design paths entrepreneurs explore. To that extent, recent design theories, typically Concept-Knowledge theory (C-K theory, Hatchuel & Weil, 2009), have proposed models of creative reasoning as well as methods to make explicit and/or guide the collective exploration of different alternatives.

The purpose of this article is to explore how design theory applied by entrepreneurship students offers insights around entrepreneurial behaviour and perception.

Our present study is based on the analysis of 13 groups of entrepreneurial students from Chalmers School of Entrepreneurship. After being given a course on design theory, 60 students grouped into 13 teams were given four days to apply a design theory-driven methodology to the case study they were working on. We collected our data in two ways: first, we looked at the outcomes of the working session and analyzed the production of the entrepreneurs regarding the causal logic and the effectual logic. We complemented our first-order analysis with a questionnaire to all participants, to inquire after more in-depth insights regarding their own perceived impact of the use of design theory.

Our results show that, in the application of C-K theory principles, the entrepreneurs illustrate use of effectual logic, such that they allow for expansive and robust mapping of different pathways stemming from their own means and networks. However, in their own interpretation of the use of C-K, they interpret their applied logic in a more causal frame, associating the path development to an initially set goal. This seems to indicate that effectual capabilities are developed in action, before they are made sense of cognitively. In conclusion, we suggest that future research should explore if this awareness changes over time, as the entrepreneurs become more familiar with the use of effectual logic and application of C-K theory-driven methodology.

2. Theoretical background: bridging C-K theory and effectuation

2.1 Principles of Effectuation

Effectuation is a theory developed from the study of experienced entrepreneurs which states that entrepreneurs learn to make decisions based on the means available to them, rather than objective goals (Sarasvathy, 2001). It is seen as the most effective strategy when operating in uncertainty and unpredictable circumstances, rather emphasizing the entrepreneur's own action, as that which is controllable and predictable. Effectuation is proposed as an alternative (not a replacement) to causation, which bases decision making on the ability to select and predict actions towards a specific goal (Sarasvathy et al., 2008). Causal logic, in turn, is described as a focus on achieving a desired goal through a specific set of given means. We outline causal and effectual logics in Table 1.

Effectuation builds upon five core principles: start with a given set of means focusing on what can be done, affordable loss, alliances with committed stakeholders, leverage environmental contingencies, and focus on the things you can control to shape the future when it is seen as unpredictable (Sarasvathy, 2008). The first principle, called the bird in hand principle emphasizes acting with the means available to you, outlined in three basic questions: who you are (identity), what you know (knowledge), and who you know (network). The entrepreneur uses these means to develop opportunities based on guesses about uncertain future preferences (Sarasvathy and Dew, 2005). The second principle, affordable loss, simply states 'don't spend or risk more than you are capable of loosing', again building from the premise of operating from what you know within an uncertain environment. The third principle recommends that entrepreneurs determine how to leverage unexpected outcomes, instead of working towards minimizing unexpected outcomes. "Bad" news and surprises are instead interpreted as clues for creating new markets and new opportunities. The fourth principle addresses leveraging contingencies. Entrepreneurs build partnerships with self-selecting stakeholders, who commit early on to the ventures (this is often seen as investment in the team rather than the idea). For the entrepreneurs, this reduces uncertainty regarding partnerships and enables them to co-create the new market with interested participants. The fifth principle states that to the extent you can control something, you don't need to predict it. This means that by focusing on activities within

their control, entrepreneurs know how their actions will result in the desired outcomes (Dew et al., 2009, Read et al., 2011).

Table 1. Description of causal and effectual logics

View of the future	Causal logic	Effectual logic
Basis for Taking Action	*Should:* Focus on optimal scenarios and reaching preset goals. Start with given goals.	*Can:* Focus on doing the doable and pushing it forward. Start with given means: who you are, what you know and who you know.
Attitude Toward Risk	*Expected return:* Calculate upside potential and pursue the best opportunity	*Affordable loss:* Calculate downside potential and risk no more than you can afford to lose
Attitude Towards Others	*Competitive:* Set up transactional relationships with customers and suppliers	*Co-creational:* Build your market together with customers, suppliers and even potential competitors
Attitude Towards the Unexpected	*Avoid surprises*	*Leverage surprises*
Underlying logic	Prediction: The future can be readily predicted. To the extent we can predict the future, we can control it.	Control/Design: Using strategies for creating a future. To the extent we can control the future, we do not need to predict it.

2.2 Choosing a design theory model to support effectuation

What is required to support effectual logic? One way of modelling the effectual logic of entrepreneurs is to model the diversity of exploratory activities of an entrepreneur: the paths he/she explores but chooses not to build upon, the knowledge he/she both starts with and acquires, and the resources he/she mobilizes in his/her network of stakeholders. Making sense of effectuation implies highlighting the generativeness of the design process, i.e. the possible different design paths entrepreneurs explore. To that extent, classical brainstorming approaches that trace the generation of ideas offer to support a facet of effectuation but do not model the knowledge learning, nor do they explain the relation to other stakeholders. Indeed, brainstorming, lateral thinking or divergent thinking are different creative approaches, none of which elaborate on any formal models of the creative design phenomenon. Instead the principles of these different creative approaches are mostly expressed through metaphors, which do not offer a model to interpret effectual logic.

Therefore, we need to mobilize a theoretical framework that builds on a process of integration as creative thinking and design, which are no more seen as two different rationalities but as a unique model of thought built on the acknowledgement of the undecide-ability and unknowness that is necessary to begin any genuine design process. Recent design theories have proposed models of creative reasoning as well as methods to make explicit and/or guide the collective exploration of different alternatives.

2.3 Elements of C-K theory

C-K theory is a unified theory of design developed after many empirical studies on design processes (Hatchuel and Weil, 2009). It is both a design theory and a theory of reasoning in design. It is based on the distinction between two spaces that are continuously expanding: a space of knowledge ("K-space"), defined as a set of proposals that all have a logical status; and a space of concepts ("C-space") defined as a set of undecidable propositions, that is to say, propositions that have no logical status. The K-space is a mapping of all the necessary knowledge for understanding and conducting a project to success; the C-space is tree-structure of undecidable propositions, where each node of the tree corresponds to a partition (in the mathematical sense) of the mother concept into several sub-concepts.

Different tools and methodologies have been developed from this initial theoretical framework (Hooge et al., 2012). Specifically, C-K theory makes it possible to graphically represent design activities by using C-K diagrams (Agogué et al., 2014). These diagrams include the two spaces, the C-space and

the K-space, and represent the gradual expansion of those two spaces. A C-K diagram is therefore a tool that can be used as a model of a design process, i.e. the state at a precise time of the available knowledge and various attributes added to the initial concept during the design process. A C-K diagram can be used in different ways: to allow a designer to represent the design process and to be used as a chart to support an enriched discussion with other actors. By using a C-K diagram, an individual or a group can generate discussions covering several dimensions: what knowledge or attributes have been deepened, what are the alternatives that have been discussed and/or chosen, what design paths remain unexplored (Agogué et al., 2014).

2.4 Using C-K diagrams as support to effectuation: an analytical framework

How can therefore a design theory framework be of use to support the causal logic and the effectual logic of entrepreneurs? We propose thus to interpret the causal and the effectual logic with C-K theory elements (and summarize it in Table 2).

First, let's focus on the causal principles described by Sarasvathy. To start, causal logic involves the development of optimal scenarios and reaching preset goals, which can be translated as the explication of the knowledge at hand and of the definition in the knowledge base of the defined goals of the entrepreneurship journey. Anticipating expected return means to explore one linear path in the C-space (as well as associated part in the K-space) and evaluate the value and the associated risks of this single path. Then, the focus on the competitive landscape involved in the causal logic can be seen as focusing on the existing paths that already exist and explored by the different stakeholders, and avoiding environmental contingencies means avoiding surprises, i.e. avoiding the emergence of disruptive concepts. Last, the predictive principle in a causal logic refers to the control and anticipation of all known possibilities, requiring an extensive mapping of the K-space.

Table 2. Interpretation of causal and effectual logics in C-K theory framework

	Description	**Interpretation in C-K theory framework**
Causal Principles	Focus on optimal scenarios and reaching preset goals	Make explicit the use of your knowledge base
	Focus on expected return	Explore one linear path and evaluate odds
	Focus on competitive landscape	Focusing on the existing paths that you are not currently operating in
	Avoid environmental contingencies	No disruptive concepts (avoiding introduction of expansion in the C-space)
	Predict the future in order to control it	Control and anticipation of all know possibilities (extensive K mapping)
Effectual principles	Start with a given set of means	Explicit both the knowledge base and the conceptual paths at your disposal
	Focus on affordable loss	Evaluating multiple paths, as well as the ability to shift from one path to another (understanding the link between C and K)
	Focus on strategic alliances	Expanding in both C and K to explore all possible paths, regardless of existence
	Leverage environmental contingencies	Explore all alternatives including disruptive concepts
	Control a future seen as unpredictable	Achieving robustness, other possible alternatives

If we now look at the effectual logic, the bird in the hand principle is working with the means at hand, based upon making the knowledge base more explicit and display and of the different paths of solutions that are achievable (some in collaboration with other stakeholders). Focusing on affordable loss can be seen as evaluating multiple paths, as well as the ability to shift from one path to another (understanding the link between the C-space and the K-space). Focusing on strategic alliances, in a C-K framework, would be expanding the C-space and the K-space relatively to the competencies and resources of associated stakeholders. This would also translate into interpretation of value propositions

not only for the entrepreneur him/her-self, but also for the network of stakeholders. This increases value options across the network of actors. Leveraging the environmental contingencies can be understood as exploring the Concept space in C-K theory. Robustness, as seen in C-K theory, is about building alternatives that are able to resist variations of context (Hatchuel et al., 2011). In relating to the principles of effectuation, such alternatives can be seen to be adaptable within a dynamic environment, and thus are not predicated by a need for a predictable logic to execute planning.

3. Method and Material

3.1 Entrepreneurship master students at Chalmers University, Gothenburg, Sweden

Our present study is based on the analysis of 13 groups of master students in entrepreneurship from the Chalmers School of Entrepreneurship (Goteborg, Sweden). After being given a course on innovative design theory, 60 students grouped into 13 teams were given four days to apply a design theory-driven methodology to the case study they were working on.

The C-K assignment given to the students were to be carried out on a real-life but shelved innovation case, called Samba Sensors. The basic technology behind Samba Sensor is the pressure sensor depicted in Figure one, where fiber optics allow for pressure measurements in a variety interesting areas, ranging from hearts and other body organs, through car combustion, to difficult to access production environments, such as oil extraction and telecom monitoring. Samba Sensor basically is a technology platform consisting of eight patents covering basic functions of the sensor as well as different areas of use.

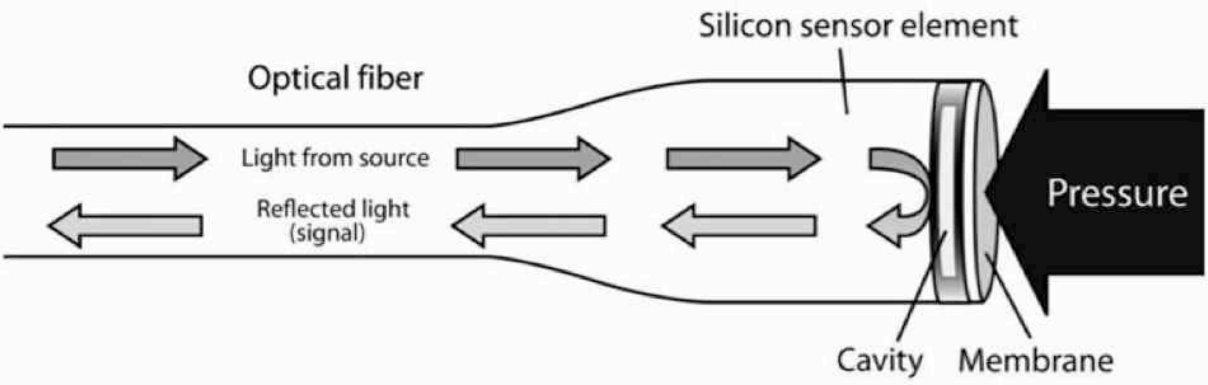

Figure 1. Principal illustration of the basic technology platform of Samba Sensors

Prior to the introduction of the C-K assignment, the 13 student teams had carried out an intellectual asset assessment assignment. Here they needed to dwell into the specifics of the patents and make initial choices and valuation of what aspects of how to utilize the technology platform. Although none of the students had previous history with this particular innovation areas, they were at least reasonably technology-savvy because of the initial assignment, to dare to start exploring possible designed futures based – more or less – upon the given technology platform. The C-K assignment did not force the students to eventually build upon any of the initial patents offered by Samba Sensors. Rather, the Samba case and the preceding intellectual asset assessment should be seen as giving the student teams very specific and yet flexible “birds in their hands”.

3.2 Data collection

We collected our data in two ways: first, we analyzed the outcomes of the assignment and analyzed the production of the entrepreneurs regarding the reflexivity of their approach, the explored paths – explicitly, the aim of the production and the strategy entrepreneurs built on it. We then complimented this first-order analysis with a questionnaire to all participants, in order to inquire after more in-depth

insights regarding the impact of the learning of design theory on the effectual logic. Thus, we acquired a dual perspective data on how a design theory framework can be used as a support to either a causal and/or an effectual logic: using Argyris' and Schön's learning terminology (Argyris and Schön, 1999, Schön, 1983), we aimed at collecting data that reflects both "theory in use" and "espoused theory".

We received a 45% (27 of 60) response rate on the questionnaire addressing participant insight into the use of applied design logic on their entrepreneurial process.

3.3 Data analysis: a combined quantitative and qualitative approach

We analyzed those data on two levels of analysis, according to the means of data collection and our analytical framework. First, we scored each C-K diagram produced by the 13 groups according to the five principles of the causal logic and the effectual logic according to the interpretation of both logics in a C-K framework (see Table 3).

Table 3. Data analysis matrix

Causal Logic	**Yes/no**	**Effectual logic**	**Yes/no**
Map the knowledge space	0/1	Map both spaces	0/1
Explore one linear path and the value it holds (explore one path in C)	0/1	Explore different alternatives and build on value of the link btw C and K (capability to shift design path)	0/1
Map the missing knowledge and the existing alternatives	0/1	Map the unknown missing knowledge and the unknown paths	0/1
No disruptive concept	0/1	Disruptive concept	0/1
Control and anticipation of all possible scenarios / Extensive K mapping	0/1	Robustness	0/1
TOTAL	**0/5**	**TOTAL**	**0/5**

To analyze our second-order data, the questionnaire included both open-ended questions, as well as one multiple-part Likert-scale question. The four open-ended questions were in regards to the utility and ease of use of the design theory in regards to their developing case. The Likert-scale question investigated causal vs. effectual use.

4. Results

4.1 First-order analysis: coding C-K diagrams and evaluating causal vs effectual logic

The participants delivered 13 case analyses utilizing C-K design theory. As listed in Table 4, the 14 groups all chose different types of C0 to explore.

Table 4. A diversity of uses of C-K theory from a shared initial start point

Team	C_0
1	Lower Product Price
2	Innovative pressure measurement in the biomedical sector
3	User-friendly, less traumatic and more accurate blood pressure measuring device for animals
4	Provide our device with energy inside the body
5	Find the commercialization strategy that creates the maximum profits during the patent life-time
6	New Business model/ application for fiber optic patents
7	Physical integration of the optical fibre pressure measurement device into a drip irrigation system
8	Pressure measurement device
9	An application for samba sensors technology
10	More efficient continuous pressure measurement in the human body
11	Identify a better strategic way to package the Samba Sensor technology and get it to the market
12	Identify a useful application area for Samba Sensors pressure measurement device.
13	Safer, more accurate safety system by pressure measurement

Figure 2 displays the scoring of the C-K diagram each team produced comparing the causal and effectual scores.

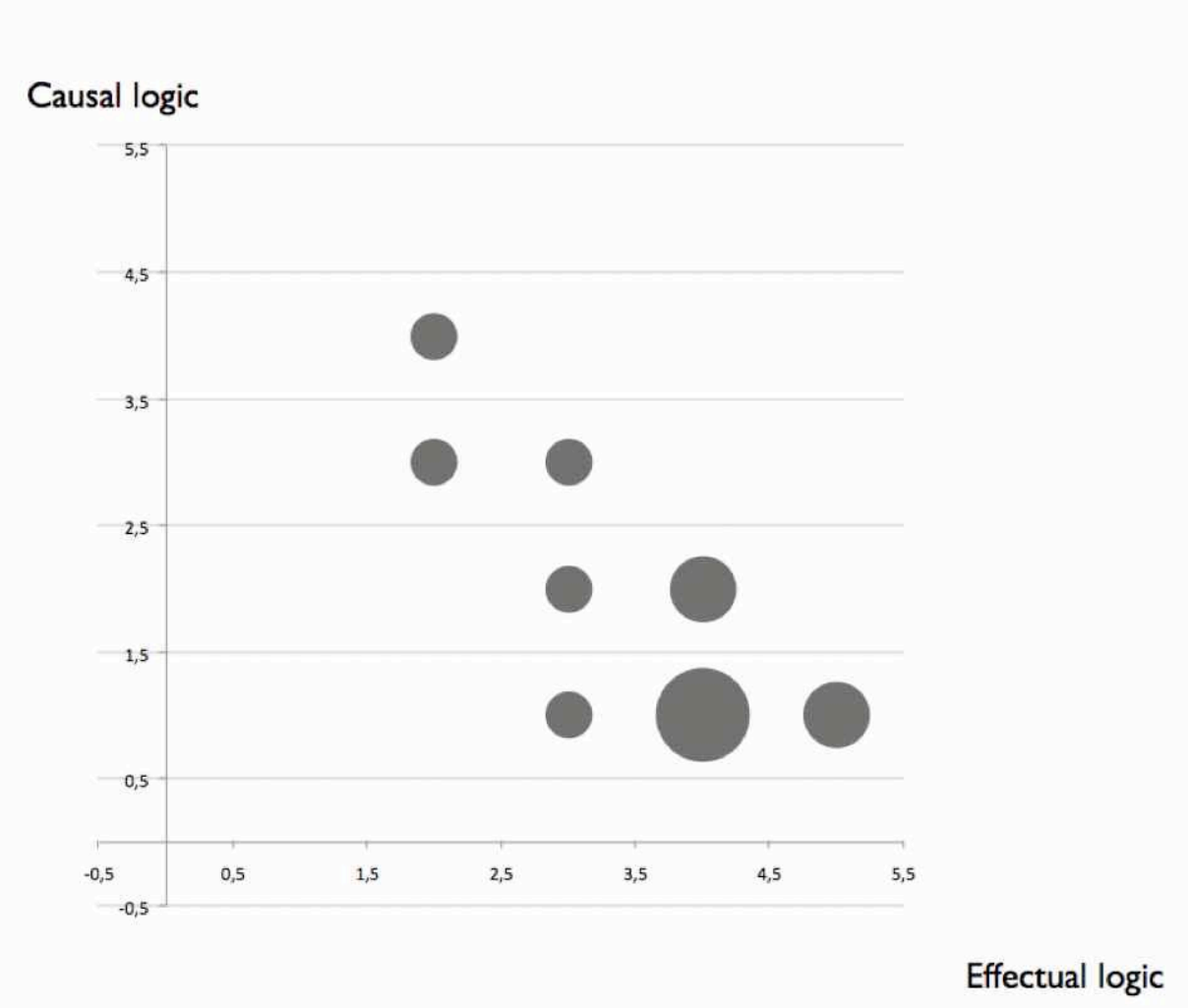

Figure 2. First-order analysis of the outcomes of applying design theory-driven methodology: effectual vs. causal logic score

Figure 2 shows that in applying a C-K theory framework to work on their cases, students tend to operate a trade-off between the two logics, but mostly, their use of a design approach allows them to conduct an effectual logic.

4.2 Second-order analysis: participants perception

Regarding the first question, a majority (21 of 27 respondents) stated that the theory was definitely or to some extent useful to the development of their case. However, of these 21 respondents, more than half (11) said that they felt they would have benefited further from the theory if it had been introduced to them earlier in their process of working with their case. The second question asked if the theory was easy to understand. Again, the majority of the 27 respondents stated either, yes, it was easy to understand, or it was to some extent easy to understand (13 and 6 respectively). Some respondents specified a difference between the ease of understanding the design theory when presented in a more simplified example, and a decrease in understanding of the theory when applied to a more complex example. When asked if enough time was allocated to presenting the design theory, the large majority of respondents (21) answered yes; that they felt the explanation time was sufficient.

Moreover, Likert-scale questions asked participants to rate the association of the applied design theory in terms of four different orientations: product-orientation, goal-orientation, process-orientation and actor-orientation. The first two orientations refer to the causal logic, the two last to the effectual logic. Figure 3 compares the perception of causal and effectual logics by the participants based on the computation of the likert-scale scores.

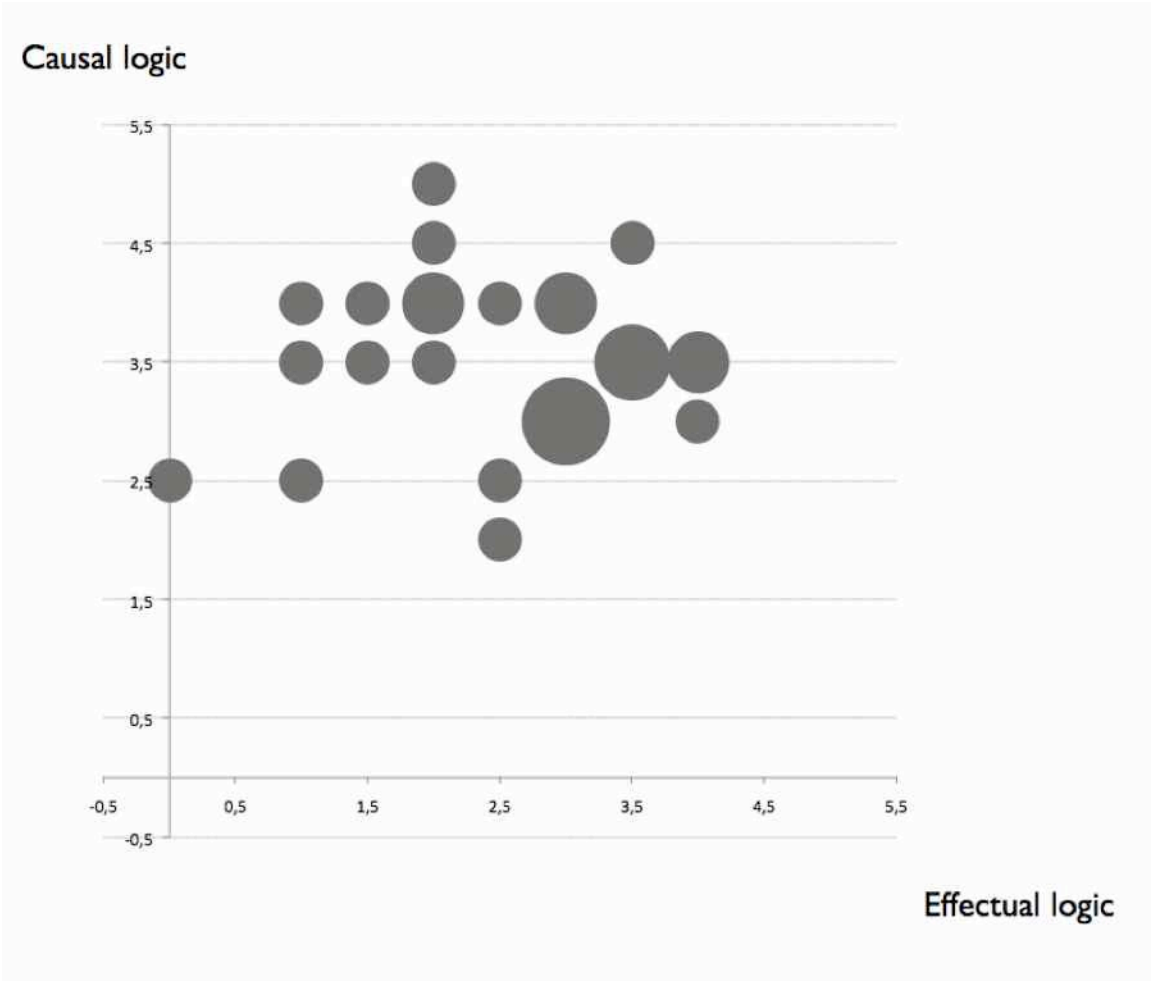

Figure 3: Student perception of use of logic

Participants associated higher utility of design theory (average rating of 3.74 out of 5) as applicable to product or service development, and felt that design theory was least applicable to actor (stakeholder) development (average rating of 2.22 out of 5). Figure 3 shows that students tend to interpret their use of C-K theory as a causal logic.

In other words, when comparing figure 2 and figure 3, the entrepreneurs are inclined to express their "entrepreneurial perceptions" and "entrepreneurial whereabouts" in more casual terms then reflected in their actual actions. For instance, one respondent who valued his/her action of using C-K theory as more causal than effectual logic (causal score: 4; effectual score: 1) however described his/her use as quite effectual: "*We used mostly as a way to after construct and understand how we actually went from ideas and concepts through knowledge and finding a new idea*".

5. Discussion and Conclusions

To date, there is very little documented evidence around entrepreneurs applying design theory into their creation of new product and ventures. This is remarkable given wide-spread view that many entrepreneurs are innovative creators of new products, services and ventures. One explanation to this lack of understanding might be that both entrepreneurship and design thinking has been biased towards a more predictive and causal logic.

This study is a first attempt to study how entrepreneurship students behave and reflect when introduced to a design theory – specifically C-K theory – that arguable stands out as enabling both generation of new concepts and knowledge as well as allowing convergence upon preferred concepts. C-K theory is thus not biased towards either causation or effectuation and thus offers a tool for studying entrepreneurial behaviours as well as entrepreneurial perceptions and identity.

Our results show that, in the application of C-K theory principles, the entrepreneurs primarily illustrate use of effectual logic, such that they allow for expansive and robust mapping of different pathways. However, in their own interpretation of the use of C-K theory, they interpret their applied logic in a more causal frame, associating the path development to an initially set goal. This seems to indicate that effectual capabilities are developed in action, whereas such behaviours end up being interpreted in more causal terms in when reflected upon in hindsight.

There are some different potential paths to pursue based upon this initial study. Firstly, if effectual logic is something that entrepreneurship educations wish to teach and obtain, then the C-K design theory offers a way to increase reflectiveness and appreciation around actual effectual behaviours and also a tool to allow entrepreneurial students to gradually change their identities into being relevant with actual behaviour. Thus C-K theory could help nascent entrepreneurs to avoid pitfalls and problems coming from espoused and more causal explanations. Regardless of how much the design method actually has affected the efficiency, creativity of effectiveness of an entrepreneurial development process, this adaptation of espoused theories towards actual theories in use is a worthy learning outcome in itself, potentially helping nascent entrepreneurs to gain a more effectual identity, found to be expressed and used by more experienced entrepreneurs (Sarasvathy, 2008).

Secondly, a key question only touched upon in this study, is how the C-K design method impacts actual design capabilities of an entrepreneurial team. The current study indicates that C-K theory could have had larger impact if introduced earlier in the education. There are also obvious limitations in having a shelved case and only a short four-day assignment. Hence, as regards impact from using design theory in entrepreneurship education, there are yet no strong conclusions to be drawn. However, this study does offer a framework for relating a design theory to the logics of effectuation and causation. This together with the generative capabilities of the students teams to all have different use of the C-K method strongly indicates that the current set-up of introducing C-K theory to entrepreneurship students holds a lot of merit. In other words, we suggest further exploration of design theory methods into entrepreneurship educations and context, given that they are sensitive to both effectuation and causation logics.

Finally, although the current study indicates behavioural preference towards effectuation and cognitive preference towards causation, this should not automatically favour one logic at the expense of the other. Rather, design theory in general and perhaps C-K theory in particular seem to offer a very valuable tool to further explore actual entrepreneurial behaviour as well as entrepreneurial perception and identity. The current study shows that even a relatively controlled educational setting can offer some insights. Further studies could look into use of C-K theory more longitudinally as well as related to more real life entrepreneurship situations.

References

Agogué, M., Hooge, S., Arnoux, F. & Brown, I. 2014. Introduction to C-K theory, Paris, Presses des Mines.

Argyris, C. & Schön, D. A. 1999. On organizational learning.

Chandler, G., Detienne, D., Mckelvie, A. & Mumford, T. 2011. Causation and effectuation processes: A validation study. Journal of Business Venturing, 26, 375-390.

Dew, N., Read, S., Sarasvathy, S. D. & Wiltbank, R. 2009. Effectual versus predictive logics in entrepreneurial decision-making: Differences between experts and novices. Journal of Business Venturing, 24, 287-309.

Hatchuel, A., Le Masson, P., Reich, Y. & Weil, B. 2011. A systematic approach of design theories using generativeness and robustness. In Proceedings of the18th International Conference on Engineering Design (ICED11).

Hatchuel, A. & Weil, B. 2009. C-K design theory: an advanced formulation. Research in Engineering Design, 19, 181-192.

Hooge, S., Agogué, M. & Gillier, T. Year. A new methodology for advanced engineering design: Lessons from experimenting CK Theory driven tools. In: International Design Conference-Design, 2012.

Perry, J. T., Chandler, G. N. & Markova, G. 2011. Entrepreneurial Effectuation: A Review and Suggestions for Future Research. Entrepreneurship Theory and Practice, 36, 1-25.

Read, S., Sarasathy, S., Dew, N., Wiltbank, R. & Ohlsson, A.-V. 2011. Effectual Entrepreneurship, London, Routledge.

Sarasvathy, S. D. 2001. Causation and Effectuation: Toward a Theoretical Shift from Economic Inevitability to Entrepreneurial Contingency. The Academy of Management Review, 26, 243-263.

Sarasvathy, S. D. 2008. Effectuation: Elements of Entrepreneurial Expertise, Cheltenham, UK, Edward Elgar.

Sarasvathy, S. D. & Dew, N. 2005. Entrepreneurial logics for a technology of foolishness. Scandinavian Journal of Management, 21, 385-406.

Sarasvathy, S. D., Dew, N., Read, S. & Wiltbank, R. 2008. Designing Organizations that Design Environments: Lessons from Entrepreneurial Expertise. Organization Studies, 29, 331-350.

Schön, D. A. 1983. The Reflective Practitioner: How Professionals Think in Action, Aldershot, UK, BasiAshgate ARENA.

Corresponding author: Marine AGOGUE, PhD - Mines ParisTech, Center for Management Science 60 Boulevard Saint-Michel, 75272 Paris Cedex 06, France
00 33 1 40 51 92 08 – marine.agogue@mines-paristech.fr

Mats LUNDQVIST is professor at Chalmers University of Technology, department of Technology Management and Economics (mats.lundqvist@chalmers.se) and Karen WILLIAMS MIDDLETON is a senior lecturer at Chalmers University of Technology, department of Technology Management and Economics (karen.williams@chalmers.se).